

# Tool Package Training – Mask Design (v1)

## Exercises

### Exercise1: Getting started

Install L-edit on your computer.

You can find more information about mask design in the official manual L-Edit guide called Layout Editor that you find in the Help function of L-edit.

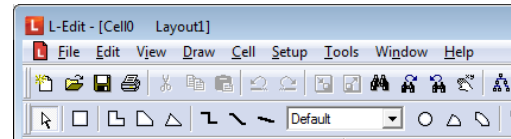
The in [Beginner guide to mask design using Clewin](#) is also useful even though it contains specific guidance for Clewin users.

Watch the introduction videos:

L-Edit: <https://www.youtube.com/watch?v=Ejtpzxd4ZzQ&list=PLZtOmgn4ITS4GXkBxXzull7BR3KxOutm9>

**Exercise guidance.** Small exercises to ensure that you come around the basics of drawing in L-edit.

- 1) For your own convenience it is good idea first to define your wafer size so that you do not draw outside the wafer limits.
  - a) Select the Layer \*\*\*\* Special Utility Layers \*\*\*\* in the Layer menu to the left of the screen.
  - b) Draw a circle with center (0,0) and the radius/diameter of your wafer (normally 100mm or 150mm)
  - c) If you cannot find a circle on the toolbar then right click on the toolbar with an arrow, square, ... and select "All angle and curves" on the menu that pops up. Three more icons are now added to the toolbar.



- 2) Choose a layer in the Layer menu (for instance layer "Active"). Make a rectangle that is 50 um wide and 35 um high in layer 0. Place the rectangle such that the lower left corner is in the coordinates (-100, 0). Make a copy of the rectangle and place it such that the center is in the coordinate (-125,-25). Enlarge the rectangle with 50 % such that the upper right corner stays in the coordinates (-100,-7.5) and rotate it counterclockwise 45 degrees around the upper right corner. Make a shape that connects the two lower corners of the smaller rectangles with the two upper corners of rotated rectangles (You probably need to zoom to highest level to ensure no gap is present and that the corners actually overlap). Merge all three shapes into one shape (this act cannot be reversed). How many nodes does the shape consist of and how large is the area?
- 3) Chose or define another layer and name it *Layer 1*. Change the color and pattern to your favorite in this layer.
- 4) Make a rectangle that is 50 um wide and 35 um high in layer 1. Place the rectangle such that the lower left corner is in the coordinates (0, 0). Make another rectangle 10 um smaller on all edges and place it next to the first rectangle you made separated 20 um and aligned to the top. Combine the two rectangles in a Cell named *Rectangles*. Open "Design Navigator under the View pane. Here a hierarchy is shown where the *Rectangles* are below the MainSymbol named *Cell0*.

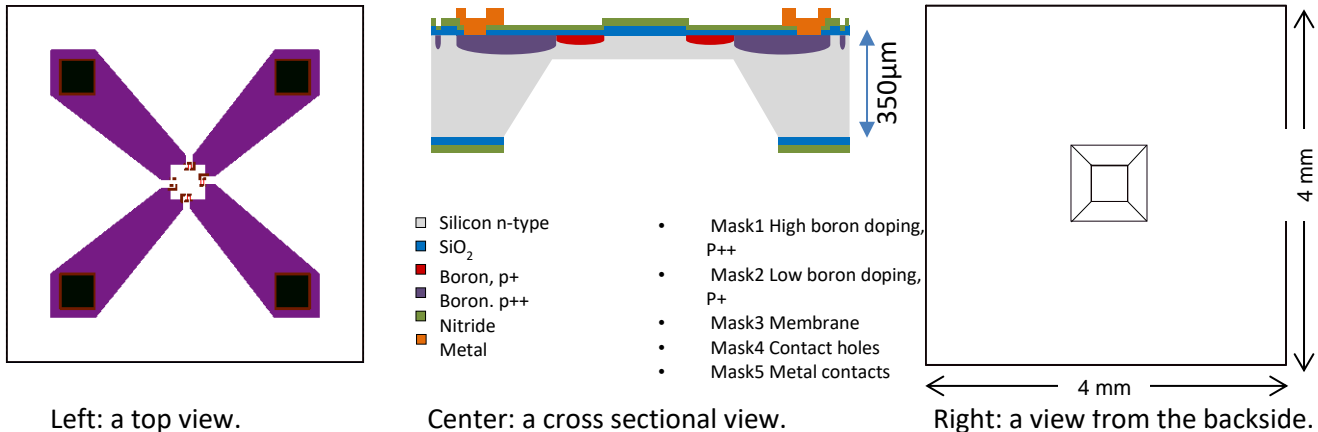
- 5) Create a circle in the MainSymbol (*Cell0*) with a diameter of 200  $\mu\text{m}$  with a square hole in the center with an edge length of 80  $\mu\text{m}$ . Center the structure in (100,-200). How do you make the figure?
- 6) By the way the circle should have been drawn in a layer named layer 2.
- 7) Create a new Cell called *Shapes*: in the Main Menu Bar click Cell and then New. Change the name of the cell and click ok.
- 8) By using the shaping tool create the 4 figures shown below in the symbol *Shapes*. The 1<sup>st</sup> shape from the left is roughly 150  $\mu\text{m}$  wide and 200  $\mu\text{m}$  high, the 2<sup>nd</sup> is 270  $\mu\text{m}$  wide, the 3<sup>rd</sup> is 200  $\mu\text{m}$  high and the outermost to the right is 200  $\mu\text{m}$  high and 250  $\mu\text{m}$  wide:



- ii) Describe in words how you made the 4 shapes List from left to right.
- 9) Open the design navigator and drag the symbol *Shapes* into the MainSymbol *Cell0* and place it next to the circle with the square hole. If you expand cells in the design navigator window the hierarchy of your design will appear in the window:
  - i) You should now see two Cells (*Rectangles* and *Shapes*) at the same hierarchy level under the MainSymbol *Cell0*.
- 10) To make an array of the smaller rectangle in the symbol *Rectangles* open the cell named *Rectangles* by double clicking the cell in the layout, in the design navigator or choose the cell from the list that appears in the menu under Cell open and make a new symbol of the smaller rectangle, named *Rectangle\_small*. While staying in the symbol *Rectangles* duplicate the smaller rectangle in an array of 100 rows and 80 columns separated with a 20  $\mu\text{m}$  space in both directions. What happens in the array if you open the symbol *Rectangle\_small* and change the size of the small rectangle by Ctrl E?
- 11) What happens if you open the symbol *Rectangles* and scale the array with a factor of 5 using Ctrl E, what if you scale with a factor of 0.5?
- 12) Create an empty cell and name it *Squares*. Make a square 500x500  $\mu\text{m}$  in the empty cell with bottom left corner in (0,0) in *Layer1*. Make a smaller square (400 x 400  $\mu\text{m}$ ) on top of the first square in *Layer Active*. Align the two squares around their common center point. Open *Cell0* and instance the symbol *Squares* here and place it in the coordinate (0,-1000). Describe how you do this.
- 13) Save the layout with a new name as a tdb file as well as a gds file and cif file. Before exporting the file you should give every single layer that you use in the layout a unique CIF name and GDS number. This is done in the setup layers or by double clicking the layer. Further the fabrication cell should be defined before saving/exporting. This is done by clicking Cell in the toolbar and chose fabricate. Then choose the cell to fabricate and click ok. You should now see a pink *f* left of the cell to fabricate (*Cell0*).
- 14) Send the files to [Kabi@danchip.dtu.dk](mailto:Kabi@danchip.dtu.dk) and you can move on to Exercise 2 and 3 (see below).

## Exercise 2: Design making

In this step you are going to make a mask layout for a pressure sensor. An example of a pressure sensor is shown below.



Left: a top view.

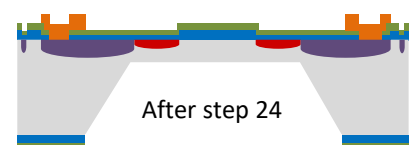
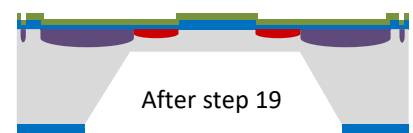
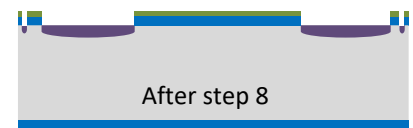
Center: a cross sectional view.

Right: a view from the backside.

It will take 5 different masks (i.e. 5 different layers in the design file) to make the shown design; one for the interconnections, high boron doped; one for the piezo-resistors, low boron doped; one for the pressure membrane and finally one for the metal contacts. In the layout we have made the first 2 masks. Your task will be to complete the layout with 3 more masks; the membrane, contact holes and contact metal.

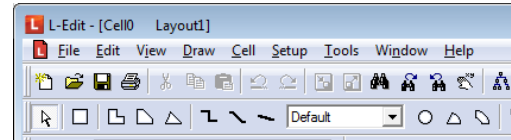
A simplified process flow for the pressure sensor could be:

1. RCA Clean wafers
2. Thermal oxidation of wafers
3. LPCVD nitride deposition
4. Photolithography on front side.
  - Mask 1: open holes in nitride and oxide for high boron doping
5. Etch nitride and oxide on front side
6. Resist strip
7. RCA Clean wafers
8. Boron doping p++
9. Photolithography on front side.
  - Mask 2: open holes for low boron doping
10. Etch nitride and oxide on front side.
11. Resist strip
12. RCA Clean wafers
13. Boron doping p+, the p++ area will also be p+ doped in this step
14. Thermal drive in and oxidation
15. LPCVD Nitride deposition
16. Photolithography on back side.
  - Mask 3: open hole on back side for membrane etching
17. Etch nitride and oxide on back side only
18. Resist strip
19. KOH etch of Silicon
20. Photolithography on front side.
  - Mask 4: open contact holes
21. Etch nitride and oxide on front side
22. Photolithography on front side. Negative tone resist.
  - Mask 5: define metal contacts
23. Evaporate metal
24. Lift-off process

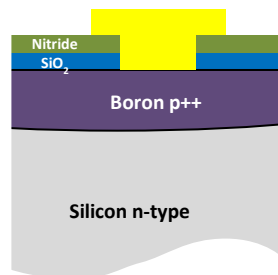


**Exercise guidance.** Getting started with the pressure sensor design:

1. Start to open the file Exercise pressure sensor.tdb. Open the design navigator and you will see the hierarchy of cells already made. The *MainSymbol* is empty.  
For your own convenience it is good idea first to define your wafer size in the *MainSymbol* so that you do not draw outside the wafer limits:
  - a. Select the Layer \*\*\*\* Special Utility Layers \*\*\*\* in the Layer menu to the left of the screen.
  - b. Draw a circle with center (0,0) and the radius/diameter of your wafer (normally 100mm or 150mm)
  - c. If you cannot find a circle on the toolbar then right click on the toolbar with an arrow, square, ...  
and select "All angle and curves" on the menu that pops up. Three more icons are now added to the toolbar.



2. You can now instance the cell *SensorDie* in the *MainSymbol*. Either by dragging the cell from the Design Navigator into the *MainSymbol* or by pressing *I* while having *MainSymbol* active and then select the cell *SensorDie* from the list that pops up.
3. Define a layer in which the membrane should be made and draw the membrane in an appropriate Cell. The opening for the membrane has to be larger than the final membrane size, due to the nature of the used etch (KOH) and it should be centered such that the strain gauges are close to the edge of the membrane still allowing for a possible misalignment of 5-10  $\mu\text{m}$ . (A membrane opening of  $850\mu\text{m} \times 850\mu\text{m}$  will result in a membrane size of  $410\mu\text{m} \times 410\mu\text{m}$  in a  $311\mu\text{m}$  deep KOH etch).
4. Define layers for the masks forming the contacts of the pressure sensor. The metal contacts should be  $500\mu\text{m} \times 500\mu\text{m}$  and the contact hole should be somewhat smaller to ensure fully coverage of the hole with metal in case of misalignment. The contacts should be placed close to the die edge on top of the Boron p++ layer in order to ease the interconnection with gold wires to a substrate for electrical measurement. A cross sectional drawing of a contact is shown below:



5. The *SensorDie* should be duplicated such that approximately 400 dies is centered on the wafer. The die size should be  $4 \times 4\text{ mm}$ . Remember to make space for the dicing lane, which will require  $100\mu\text{m}$  between each die.

## Wafer layout

### Mask definitions

Before making the alignment marks it is a good idea to consider the mask definitions first. An example of a set of mask definitions is shown below. All layers are made as 5" masks (for 4" wafers). The masks are made of Soda-lime glass with a dark periphery. The periphery and the design patterns are defined in Chromium. Each layer then has its own set of definitions: Chrome Up (CU) or Chrome Down (CD), Right Reading (RR) or Wrong Reading (WR), Bright Field (BF) or Dark Field (DF). In the example below all three layers are defined with the chromium downwards (CD):

All Layers:  
5" chromium mask  
Soda-lime Glass  
Dark periphery  
Chromium Down

Filename: TPT-maskset.cif (it can also be a gds file)  
Topcell or Mainsymbol: (name of the cell to be fabricated, often it is named Wafer)

Layer name: mask1 (for cif files it is the CIF name assigned to the specific layer and for gds files the name is the number assigned to the specific layer)  
Mask type: Dark Field, Right Reading  
Text: DTU Danchip – Karen Birkelund - August 2016 - Projectname – Nitride etch

Layer name: mask2  
Mask type: Bright Field, Right Reading  
Text: DTU Danchip – Karen Birkelund - August 2016 - Projectname – Deep Si Etch

Layer name: mask3  
Mask type: Bright Field, Wrong Reading  
Text: DTU Danchip – Karen Birkelund - August 2016 - Projectname – Metal

Each mask layer in the file has to be addressed. The text is an identifier that will be written in the edge of the mask for your information only and will hence not appear on the wafers. Notice that the definitions are made for all layers with Chromium Down. Then right reading masks are for one side of the wafer while wrong reading masks are for the other side of the wafer.

### Alignment

All the individual layers in the design need to be aligned to each other in the order they are processed. It can be a good idea to define all alignment marks in the 1<sup>st</sup> mask, such that all forthcoming masks can be aligned with the same accuracy to the first mask. However, sometimes it can be convenient that for instance the 4<sup>th</sup> mask is aligned more precisely say to the 2<sup>nd</sup> mask than to the 1<sup>st</sup>. In that case a new mark can be defined on the 2<sup>nd</sup> mask such that aligning the 4<sup>th</sup> mask is independent of the misalignment of the 2<sup>nd</sup> mask to the 1<sup>st</sup> mask.

It cannot be recommended to have only one single mark for all masks to be aligned to, because it can be quite difficult to preserve the mark during processing, especially in deep etches. You can find design rules for the alignment marks in [Beginner guide to mask design using Clewin](#)

### Monitor structures

It is wise to incorporate monitor structures on a mask design for the individual processing steps.

In the folder Library you will find different patterns like alignment marks, flat alignment marks and monitor structures and test dies for electrical measurements. You are free to use these in your layout or you can make your own.

### Exercise 3 - Making the overall wafer layout

1. Make and place monitor dies at strategic positions in the mask design. Argue why they are placed as it is.
2. Incorporate guiding marks for the dicing in an appropriate layer.
3. Make flat alignment mark in your mask design, this should be on the first mask to be processed.
4. Make alignment marks for each layer in the mask design. You want to align with high accuracy (1-3  $\mu\text{m}$ ). Remember that the polarity of the mask influence the way they are made, since you need to be able to see what is on the wafer beneath the mask you are going to align to. Also remember that the field in an aligner typically is 300  $\mu\text{m}$  x 300  $\mu\text{m}$ .
5. Where there is room you can place your name and other fun stuff as Global ID's
6. By the way it has been decided that the contact holes on all sensor dies should be circular with at diameter of 400  $\mu\text{m}$ , while the metal contact should remain as a square.
7. We also need to know the fraction of the surface of a 4" wafer (diameter 10 cm) that is covered with metal in the design. L-Edit has an area calculator, choose **Tools->Add-Ins->Area calculator** in the menu bar. Before making the calculation you should save a copy of your design, flatten your design by choosing **Cell->Flatten** in the menu bar (this action cannot be reversed, why you should do this action in the copy of your design), make the layer which area you want to calculate visible, all other layers should be invisible, mark the area that should be calculated and execute the calculator. You should be aware that the calculated fraction (percentage) is with respect to your defined rectangle and not a disc like a wafer. Do the calculation with respect to a 4" wafer. You can ignore the wafer flats in the calculation.
8. Export the file as a cif file as well as a gds file. When saving in cif or gds formats it is important that all layers used in the layout have a unique CIF name or unique GDSII-number. You can check that out by for each layer used in the layout in the Setup Layers choose general and type a number in the GDSII number field and a CIF name in the dedicated field.

Finally you are ready to make a mask order.

- Write a text file with the mask specifications as shown in the example. A negative tone photoresist is used for the mask defining the metal pads followed by a lift off (the areas that are exposed to light will the area with metal after the lift off). The other masks are to be used with a positive tone photoresist (the areas that are exposed to light will be openings in the resist).

- Send a mail with the text file containing the mask definition together with a cif- or gds-file with your layout attached to [Mask@danchip.dtu.dk](mailto:Mask@danchip.dtu.dk). In the subject field of the mail you write “**TPT Course: maskorder**”.